Sensors, Interfaces, & Networks for Metrology & Manufacturing

Program Manager: Kang B Lee
Total FTE: 3.1
Total Funding: $535,000

Goal

To revolutionize the connectivity and utilization of sensors in metrology, manufacturing, and conditioned-based maintenance to enhance industrial capability and manufactured quality.

Program Objectives

FY2004

Work with industry to adopt, develop and implement conformance testing procedures for the IEEE 1451 sensor interfaces and networking standards.

Smart Sensor Interface Development and Implementation

Develop transducer interface standard reference implementations in support of the IEEE 1451 standard development and draft specification verification/validation.

FY2005

Lead industry and government in the use of standardized sensor, networking, intranet, and internet technologies for remote metrology and tele-calibration such as SIMNet, MeasureNet, and WorldNet, and conditioned-based maintenance.

Remote Calibration and Metrology

Research and development of standard networks for remote calibration and metrology applications.

FY2005

Explore, develop, and integrate new sensor technologies such as acceleration, micro-force, acoustic, ultrasonic, micro-electro-mechanical systems (MEMS)-based sensors for application to mechanical metrology, machine tools, and conditioned-based maintenance systems.

Sensors and Sensor Integration for Condition-Based Maintenance (CBM)

Develop sensor and networking systems, connectivity strategy, and algorithm for condition-based maintenance of machines.

Ultrasonic Research and Development

Expand ultrasonic capabilities by developing improved sensors and methodologies for mechanical property measurements and process sensing.

Remote Monitoring Prototype for CBM of Machining Systems

Develop prototype implementation to demonstrate use of smart sensors for remote monitoring of machining systems for condition-based maintenance (CBM) and control.

FY2002

Apply analytic methodologies for sensor system evaluation, materials characterization, and process monitoring to aid manufacturing.

Transient Mechanical Wave Analysis

Develop analytic tools that enhance acoustic-emission and echo-signature interpretation.

Customer Needs

Sensors and actuators are important components used in a wide range of applications such as industrial automation, manufacturing process control, machinery monitoring and control, semiconductor device manufacturing, and building automation. Typical sensors include miniature electronic devices and micro-electromechanical systems (MEMS) that measure pressure, acceleration, flow, force, temperature, vibration, torque, and position. The sensor and actuator business including MEMS is a multi-billion dollar enterprise in the United States. The world sensor market is expected to grow to $42 B by the year 2008. Sensor companies are integrating digital communication, networking, and smart technologies into their devices for added product value.

However, due to the lack of a standard interface for connecting sensors to microprocessors and field networks, it is prohibitively expensive for sensor producers to develop custom interfaces to support the multitude of proprietary networks and protocols in the marketplace. Thus, sensor manufacturers are seeking to standardize interfaces for sensors. In this project, the government plays a role as convener to increase communication and cooperation within industry to identify and resolve common industry problems. This is done by sponsoring workshops and working group meetings to identify common issues for the standardization of sensor interfaces is often a good way to increase the industry communication and cooperation. These industry standards will not only solve the sensor incompatibility problem, they will also (1) minimize the risk of technology investment, (2) accelerate the development of smart sensor technology, and (3) provide opportunities for interoperability among sensors and control networks. As a result, these standards will provide enabling technology for easing the integration and networking of sensors and actuators into distributed measurement and control systems used in manufacturing. Through this effort, the government can foster development of critical smart sensor and networking technologies.

Likewise, the manufacturing community seeks improved product quality coupled with reduced costs to remain competitive. In-process sensing techniques capable of providing feedback for process control represent one method for achieving this goal. However, both the sensors and interface controllers must be robust to achieve such control in an application. The significant cost reductions available with MEMS technology and the relative ease of implementation due to sensor miniaturization are both fundamentally important issues to user communities.

The nondestructive testing community seeks improved inspection technologies for critical structures such as aircraft, pressure vessels, storage tanks, bridges, and dams. Key to these technologies is ultrasonic inspection, whose strength is that its high frequency mechanical wave pulses are able to probe solids without damaging the material. Its detected echo signatures reveal structural and material conditions that are valuable for assessing system status and product quality.

The ability to predict the failure and the remaining life of equipment and machinery will enhance productivity and save industry millions of dollars from regular time-based maintenance and corrective actions due to machine malfunction. The manufacturing and user community across multiple industry sectors can benefit from uninterrupted operation of machinery and equipment in good health with the help of conditioned-based maintenance (CBM) technology. The CBM technology involves the development of advanced sensors, sensor utilization and connectivity strategy, machine diagnostics, and prognostic modules and algorithms.

The wireless telecommunication technology has been advancing at a rapid pace, both with the increase in data communication speed and the reduction in price and compo-

nent size. Applying wireless technology to sensors will open up new ways for sensor utilization. It will ease the integration of sensors into manufacturing systems and the CBM application. Also, industry is seeking new acoustoelectronic technology for wireless system and common smart wireless sensor interfaces and communications protocols.

Technical Approach

In response to industry's need for standardized sensor interfaces, we are taking the following steps. We are taking a leadership role and participating in voluntary standardization organizations such as IEEE and ISA (International Society for Measurement and Control, formerly the Instrument Society of America) to facilitate the development of standards for sensor communication interfaces and protocols, and the development of a common-object model for networked smart sensors and actuators. We will continue to sponsor workshops and working group meetings to establish industry priorities, facilitate and actively participate in standards committees and working groups, draft standards specifications, and test for standards specifications conformance.

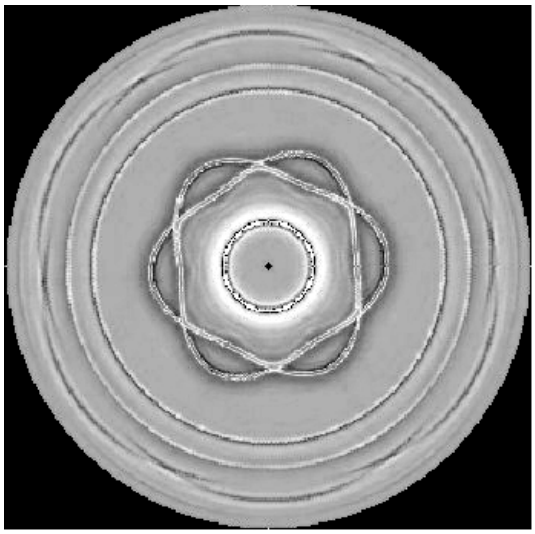
In collaboration with industry, we develop hardware and software reference implementations based on draft specifications to evaluate technical feasibility and compliance, and to provide feedback to the standards committees. We are dealing with technical issues such as digital communication protocols and timing for data and commands, transducer electronic data sheet (TEDS) for sensor self-description, and hot swap for "plug and play" integration of sensors into field networks. Other important technical issues include software interfaces for the network-independent model to interact with smart sensors and the TCP/IP (Transmission Control Protocol/Internet Protocol) Internet suite of protocols. We collaborate with industry group(s) to develop enabling technologies to demonstrate reference implementations at conferences and expositions. To broaden industry awareness of emerging interface standards, we will disseminate standardization activity information through meetings, publications, conference presentations, the Internet, and web sites. We will research, develop, and demonstrate the application of sensors, smart wireless sensors, sensor networking and Internet technologies to remote metrology, and calibration of measurement devices and instruments, and conditioned-based maintenance systems.

Based on the need for nondestructive inspection equipment for manufacturing, quality control and on-site inspection, ultrasonic transducers are developed and evaluated, and their predictive behavior modeled. One specific sensor development is a line-focus transducer sensitive to material anisotropy both at the surface and in the bulk of the material. Another sensor development is a hybrid concept combining the high-fidelity detection properties of a polymer piezoelectric with the high-efficiency generation properties of ceramic piezoelectric. The ceramic acts as the source of pulsed ultrasonic energy, while the polymer functions as the sensor and monitor of the pulse content.

MEMS technology offers significant promise in many areas of microphone miniaturization. In the case of hearing aids, greater directionality and sophisticated signal processing allows for improved hearing performance. NIST contributions to this field include microphone array device characterization and consultative support to sensor developers.

Standards Participation

- ASTM E7.06 and E28.13: Ultrasonics, Member
- Institute of Electrical and Electronic Engineers (IEEE) Instrumentation and Measurement Society TC9: Sensor Technology, Committee Chair
- IEEE P1451.1: Smart Transducer Information Model, Member
- IEEE P1451.2: Transducers to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) formats, Member
- IEEE P1451.3: Digital Communication and Transducer Electronic Data Sheet (TEDS) formats for Distributed Multidrop Systems, Member
- IEEE P1451.4: Mixed-mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) formats, Member
- U.S. Technical Advisory Group (TAG) for IEC (International Electrotechnical Commission) Technical Committee (TC) 87: Ultrasonics, Member



A polar plot of the elastic anisotropy of single-crystal quartz as revealed by ultrasonic time-resolved microscopy (patent 1999).

Accomplishments

- September FY1999 Evaluated a piezoelectric polymer hydrophone sensor to monitor nonlinear effects associated with pulsed-wave propagation in water.
- July FY1999 Designed, fabricated, and patented an ultrasonic line-focus transducer for new single-crystal materials property characterization.
- June FY1999 Contributed to and administered the IEEE P1451.1 Subcommittee to develop a draft specification, which was adopted by IEEE as an industry standard, IEEE Std 1451.1-1999.
- June FY1999 Established with the IEEE Registration Authority Committee a set of procedures for transducer manufacturers to submit proposals requesting extension TEDS ID for use with their IEEE 1451.2-compatible sensors.
- February FY1999 Constructed and demonstrated at NIST a SIMnet networking system that links the standard metrology laboratories of a dozen countries in North, Central, and South America via the Internet. This SIMnet is currently being used for the international comparison of standard procedures for digital multimeter (DMM) calibration.
- February FY1999 Established Cooperative Research and Development Agreement (CRADAs) and contracts with sensor manufacturers and users.
- October FY1999 Organized an industry group in a collaborative effort to demonstrate the 1451 technology in the ISA Technology Expo to educate the technical community and public regarding the IEEE P1451 standards.
- September FY1998 Chaired the IEEE TC9 Committee to develop a draft smart transducer interface specification that was adopted and published by IEEE as an industry standard, IEEE Std 1451.2-1997.